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THE CHARACTERISTIC OF GROUND MOTION A CAUSE THE EARTHQUAKE ACTIVITY IN NORTH SULAWESI INDONESIA

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ABSTRACT

Has done research on the study of relationship between the peaks ground acceleration (PGA) and peak ground velocity (PGV)? In this study we generated the shake map that indicate the earthquake occurance, identify the area affect and estimate the severity of ground shaking, providing information rapidly asses and mitigate damage. The relation between peak ground acceleration (PGA) and peak ground velocity (PGV) with intensity is required to estimate the risk of the earthquake in north Sulawesi. In this research, we developed empirical relationship between peak ground velocity, peak ground acceleration and observed Modified Mercalli Intensity (MMI) by using earthquake data in north Sulawesi in period 2003 to 2014. In this study we used the intensity earthquake ≥ 4.5 SR. the empirical relationship between PGV and PGA with the intensity MMI determined in this study can be expressed as:

$MMI = 4.3 \log PGV + 2.2 \quad forV < MMI < IX$

$MMI = 4.81 \log PGA - 1.5 \quad forV < MMI < IX$

The PGV and PGA based intensity are important in real-time application for damage prediction and assessment is much important for infra structure building in modern society. The analysis shows that the value pga largest to sulawesi north is 46, 33 gal and value pgv the largest 20.67 cm / s. The areas have value of the greatest intensity is kabupaten bolaang mongondow north with MMI intensity VII.

Keywords: earthquake intensity, peak ground velocity and peak ground acceleration.

INTRODUCTION

Indonesian archipelago lying between two continental shelf namely, continental shelf Asia to northwest and continental shelf Australia in south-eastern and is between two ocean namely, pacific ocean and the Indian ocean. Indonesia considered from the point of view of geodinamika, this archipelago located in convergent between three zone who the plates move against with other plates. That plates are the Eurasian Continental plate is in the northern part of the relatively silent, the Pacific Ocean plate moves westward with the velocity of 7 13 cm per year, while in the South-East Hindian - Australia plate is moving north at a speed of 6- 10 cm/year (Massinai, 2012). One of high seismicity in Sulawesi island in Indonesia I,s north of Sulawesi. This result by movement micro-tectonic plate, moving of main plate existed around Sulawesi Island and the activity of volcano in this area. Map seismotektonik north Sulawesi indicate the presence of some the structures tectonics of while or fault resulting in activity an earthquake in the high activity.Based on the historical record earthquake brackets time for 12 years in north Sulawesi and nearby happen a couple of times earthquake tectonics with force on 4, 5 SR. The impact of quake besides tsunami other impacts it was a the ground motion. The effect of the ground motion is the instability area of land use. Building more substantial infrastructure large the same thing applies to the streets that were highly active need stable areas Development of the infrastructure building

Seismic intensity has traditionally been used worldwide as a method for quantifying the shaking pattern and extent of damage for earthquakes. Through derived prior to the advent of today's modern seismometer instrumentation, it nonetheless provides a useful means of describing, in a simplified fashion, the complexity of ground motion variations found on instrument recordings. Seismic intensity is still often the only observed parameter from which to quantify the level of ground shaking following damage earthquakes in much of the world. Seismic intensity is a practical index describing, a particular site, the degree of shaking or damage. The intensity map gives the shaking pattern reflected by the earthquake damage and effects on human and infrastructure building from an earthquake. The most common information available immediately following a damage earthquake is its magnitude and epicenter. However the damage pattern is not a simple problem of these two parameters alone. More detail information is needed for emergency response agencies to assess the situation for better details and accuracy. Thus, it is highly desirable to mapping out distribution of peak ground velocity and peak ground acceleration in the potentially damage area. The reliable relationship between ground motion and felt intensity is required in generating ShakeMaps that are applicable to earthquake in north Sulawesi. The main purpose of this research are develop empirical relationship between peak ground velocity, peak ground acceleration and observed MMI (Modified Mercalli Intensity by using data from felt moderate earthquake at north Sulawesi from 2003- 2014 for earthquake intensity up to 4.5 SR.

MATERIALS AND METHOD

The history of earthquake in North Sulawesi Indonesia occupies the zone tectonics extremely active because there three large plates the world and nine other

small plates meet during the country and pathway; form the meeting slabs complex (Bird, 2003). The existence of plate's interactions among puts the region of North Sulawesi as a region very vulnerable to earthquake (Melson *et al*., 1992). The high activity of thisearthquake seen from the results of recording where in time span 1987-2009 there are more than 14,000 earthquake with magnitude M>5.0 SR. At the North Sulawesi in time span 2003 -2014 there are 193 earthquake with the magnitude≥ 4.5 *SR*. The regional basis study areas is part a northern arm island Sulawesi that is a bow the volcano formed because of tunjaman double subduction, namely lane the subduction north Sulawesi to the north of a northern arm Sulawesi and the subduction of sangihe east on the east and south a northern arm. The subduction has resulted in magmatisme activities and volcano that produces plutonic rocks and the volcano that is widespread.The subductionproduce a bow the volcano tertiary lying around Toli-Toli up near Manado. While tunjaman east sangihe allegedly active since the beginning of the quarter and produce the lanes of the volcano the quarter in the eastern part of a northern arm celebes and continuous toward the southwest up to the mount Una-Una. The properties of Rocks in north sulawesi is riodasitik until andesitik, formed in miosen-rasen with the bedrock basaltic which forms on eocene oligocene. The Bow magmatik western have rocks authors are in nature shelf which is consists of rocks the volcano -- sediment was mezosoikum -- the quarter and rocks malihan was lime. Those rocks breached multiple layer granitoid, especially granodioritik until granitik of batolit, stock and beams (Fatiyah, 2007). The earthquake source in sea at north Sulawesi situated are cause by the collision between archipelago bow the eastern north Sulawesi and west Halmahera that produces subduction mayu ridge, the subduction of north Sulawesi due to bow volcanic collision between north Sulawesi with a bow archipelago , and a group of while active fault on land. This region is situated on the boundary active plates characterized by the high level earthquake activity are considered particularly by the subduction zone of Mayu ridge. The source of subductionzone earthquakeat North Sulawesi also categorized active. The earthquake source located in the sea is also as source of the power plant o tsunami, it is proven by the mechanism earthquake on the subduction zone of North Sulawesi generally took the form of geological fault up with east to west direction. The earthquake located on land derived from some active faults and. Manado city it is estimated located near the active fault with direction North Western –South Eastern .On the geological map, pieces of Manado also apparent that they have straightness directional to North western-Southeastern close to the city Manado. The observation field at the region of Tikala, of a geological fault at the tuff sediment of Tondano is predict there are relation with the existence of fault .The age of Tondanotuff is pleistocene, so the falut wascuten it, and is estimated as the potentially active fault.

Relationship between peak ground velocity (PGV) and peak ground acceleration (PGA with Modified Mercalli Intensity (MMI)

Seismic intensity has traditionally been used worldwide as a method for quantifying the shaking pattern and extent of damage for earthquake. Seismic intensity is still often the only observed parameter from which to quantify the level of ground shaking following damaging earthquake in much of the world. The important parameters to estimate the intensity of earthquake are the PGV and PGA. Peak ground velocity (PGV) and peak ground acceleration (PGA) are the ideal choice among the ground motion parameters for shake map applications, as it is the simplest and most rapidly available parameters from seismographic monitoring. It is also the parameter most directly related to kinetic, which in turn relates to damage. Wald *et al* (1999) Any event an earthquake will generate information seismic of recording signals shaped a wave that after going through manual processes or non manual will be reading data phases (phase reading data). Seismic experienced information and collecting, processing and analysis that it becomes parameter earthquake. Parameter quake include:

a) Original time

The time of the earthquake or known as origin time is time at the time of the occurrence of the fault or runtuhan who caused the penjalaran seismic waves or earthquake.

b) Earthquake depth source

The depth of a source of earthquake is size the depth of central the fault or fallen material measured of the surface of the earth.

c) Distance epicenter and hypocenter

Episenter is the point the surface of the earth and perpendicular from hipocenter or the focus of an earthquake. Location epicenter made in a system of coordinates cartesian the ball the earth or coordinate of geographical system and expressed in degrees of latitude and longitude of earth. The depth of the earthquake source is the distance of hipocenter calculated perpendicular from the surface of the earth. The calculate of intensity and velocity of ground used the parameter of distance between epicenter to the point of observation.

d) Magnitude

The energy of earthquake (magnetude) been the large energy earthquake released by the source of the quake. In the process calculation the peak ground acceleration used magnitude surfaces waves (MS). But often data is collected use magnitude body waves (MB), if the magnitude of surface waves the surface of (MS) unknown and we only know the magnitude of body waves (MB), then magnetude of body wave can be calculated by using empirical formulation as:

$$Ms = 1, 59\ Mb - 3, 97 \quad (1)$$

e) Intensity

The earthquake intensity was the force of earthquakes based on observation effect earthquake to mankind, the building structures and environment on a particular place Intensity different with a preliminary magnitude of because intensity is the result of the observation visual on a particular place while magnitude is the result of the observation instrumental use seismograph.At an event earthquake the intensity in different settings to be equal or different the amount of magnitude always the same although noted or felt in different places. At an event earthquake the intensity in different settings to be equal or different the amount of magnitude always the same although noted or felt in different places .A scale of intensity describe the magnitude of the destruction in a location caused by gempabumi (clean dkk, 2011) Richter formulate a relation between magnitudes and intensity i.e. as follow

I_0 = 1.5(M-0.5) (2)

whereI_0 = the intensity at the epicenter and M = Magnitude (SR): As for relations intensity to the distance epicenter and intensity given by:

I = $I_0\ exp^{-b\,\Delta}$ (3)

where: I = the intensity at the observation station ,Δ = the distance of epicenter to observation station.

Peak Ground Velocity (PGV)

Each the earthquake event will be recorded by an earthquake register, that is seismograph instrument that describing the characteristic of earthquake waves vibrationn. From events earthquake, can be calculate peak ground velocity, displacement and peak ground acceleration. Peak ground velocity (PGV) is the value of largest velocity at the surface of ground that happened in an area because the seismic vibrations of the earth. Empirical formula links between PGV and earthquake intensity according to Yin-Min Wu(2003) as.

PGV = $exp\ (\frac{I-1,89}{2,14})$ (4)

where, $I = I_0 exp^{-b\Delta}$, Δ = distance of epicenter, b = 0, 00051, I_o = intensity of earthquake sources and I = the intensity at the observation stationas. Empirical formula that connects PGV and intensity above used to predict damage of the earthquake especially for storeys building that are characteristic of modern society (wu,) 2003.

Peak Ground Acceleration (PGA)

The peak ground acceleration is the parameter stating the largest change of velocity in set period of interval time bbegins from a state of silence until certain speed. Every buildings infrastructure on the ground needs stability and equilibrium. The peak ground acceleration and peak ground velocity is the important parameter in the land use especially for the heavy weight building soil local a factor that directly affecting construction. Therefore factors are is tupeakrning point of calculation of earthquake resistant building: The formula empirical links between the pga and intensity of earthquake according to yin-min wu is:

PGA = $exp\ (\frac{I-0,7}{2})$ (5)

Where $I = I_0 exp^{-b\Delta}$, Δ = distance of episenter in degree unity, b = 0,00051I_o= intensitas of source = 1.5 (M-0.5)-,I = intensity at observation station.

The research is done in the nprovinces north Sulawesi on latitude coordinate between 0^0– 2^0(North) and on longitude 122, 820- 125, 5^0 (East). This province is bounded by the north of bordering is sea Sulawesi, the east bordering by the sea maluku, the south bordering by the gulf of tomini , and on west bordering by the province of gorontalo. The map of the research earthquake daily for 12 years from 2003-2014 which includes time the data, latitude, longitude, the depth and magnitude. pgv and pga calculated by using formulas empirical that were formulated by Yin-Min Yu et all (2003). Furthermore by using the linear regression method, we sought the relationship between pgv with mmi, pga with mmi and pgv with pga. The data. Data base of PGA and PGV obtained used to map the vulnerability of the risk of earthquake in north Sulawesi. Sulawesi or Celebes situated in the region of the middle part of Indonesian archipelago and north Sulawesi is one of the arms Sulawesi. Unique form resembling the letters K with four a peninsula to veer to the east, north-eastern, southwest and south.The north province of Sulawesi is one of quite interesting in eastern Indonesia; the capital is Manado is the second largest city in the eastern Indonesia. In addition in this province there are park the beautiful park the sea and famous in Indonesia and the world namely the sea Bunakem park.But this region also including areas prone to earthquakes, because in this area there are geological active fault located on land and at sea.

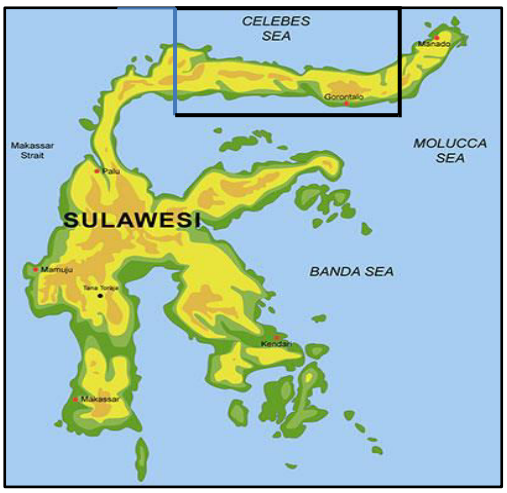

Figure-1. Map of Sulawesi Island and research location magnitude earthquake.

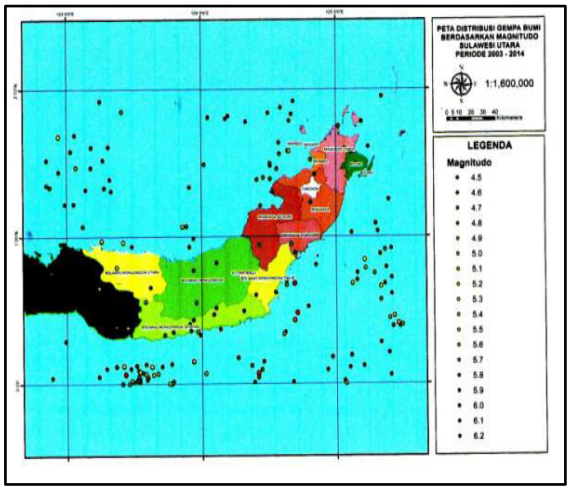

Figure-2. Earthquake map based on in north Sulawesi 2003-2914.

RESULT AND DISCUSSIONS

The result of reckoning PGV and PGA shows that in a time lapse 2003 - 2014 has occurred as many as 193 times earthquake with magnitude≥ 4.5 SR. This indicates that north Sulawesi having the high level damage earthquake. The value of PGv and the PGA was:

a) The largest value of the peak ground acceleration (PGA) t in north Sulawesi is 46, 33 gal and the smallest PGA is 12, 67 gal
b) The largest. value peak ground velocity speed land maximum (pgv) in north Sulawesi is 20.67 cm / s and the smallest PGV is 6, 15 cm / s

Through the calculations of 193 data with magnitude ≥ 4, 5 SR, we obtained the largest PGV and PGA in north Sulawesi. From the analysis of the results we obtained that there are five the damage earthquakes with large PGA and PGV on priode 2003-2014. The fifth the quake was

a) The devastating earthquake on the date 05 June 2006 with the depth of the quake source about 172, 9 km, magnitude earthquake 5.2 SR and earthquake center is at 1, 594^{o} NL - 125, 063^{0} East. This earthquake greatly influenced in North term Minahasa districts, Bitung and Manado. With the value of PGA is 22,06 gal and the value pgv is 10.33 cm / s
b) The devastating earthquake on the 17th October 2009, depth of earthquake source is 30 km and earthquake magnitude 5.2 SR. The earthquake center located at 0, 96^{o}lu - 123, 42^{o}bt. The earthquake seriously impact on north Bolaang Mongondow regency and Gorontalo. With the PGA is 23, 50 gal and value pgv is 10, 96 cm / s. this earthquake have levels of risk an earthquake the largest in north Sulawesi the intensity gempabumi is VII.
c) The devastating earthquake in June 19, 2008 by depth of earthquake 208, 5 km and magnitude earthquake 4.9 SR, the earthquake center located at 0, 949^{o} N - 124, 667^{0}E. The earthquake seriously impact at the South Minahasa, North Minahasa and Bolaang Mongondow. the PGA is 18,49 gal and PGV is 8.76 cm / s
d) The devastating earthquake on July 10 2009 by depth of earthquake 249 km and earthquake magnitude is 5. 2 SR and earthquake centre located at 0.38^{o}lu - 123, 45^{o}bt. The earthquake seriously impact at the south Bolaang Mongondow and Gorontalo. With the PGA is 21,17 gal and PGV value pgv is 9, 94 cm /s
e) The devastating earthquake in June 30th 2004, depth of earthquake 91 km and magnitude of earthquake 6.2 SR and the locate earthquake center at 0.68^{o}lu - 124, 69^{o}bt. This earthquake influence Bolaang Mongondow East and Bolaang Mongondow South. the value of PGA 46.33 gal and value PGV is 20.67 cm / s. this area shows pga and pgv most large for the region of north Sulawesi 2003-2014 period .Because this earthquake occurred in the sea point epicentre and distant observations of the regions then just caused little damage on the area.

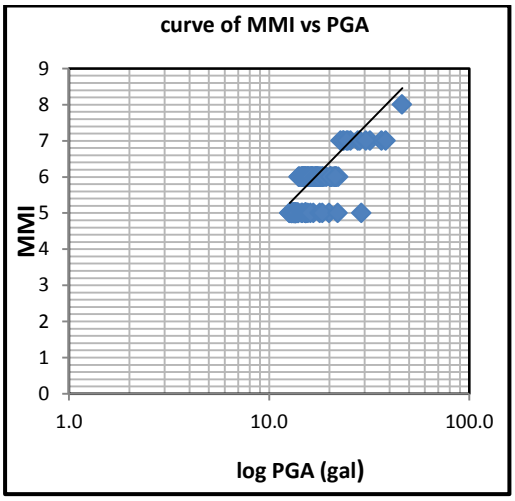

Figure-3. Curve of relationship between intensity MMI vs PGA.

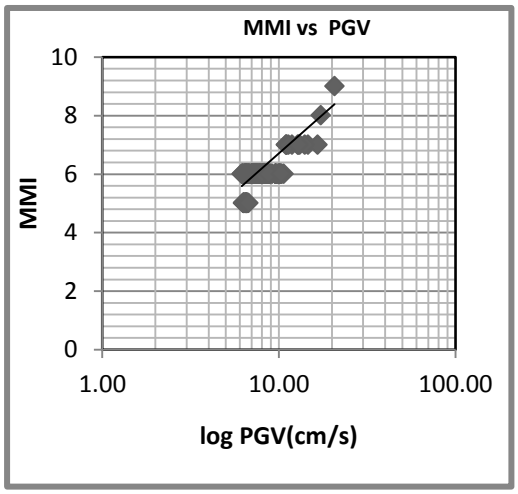

Figure-4. Curve of relationship between intensity MMI vs PGV.

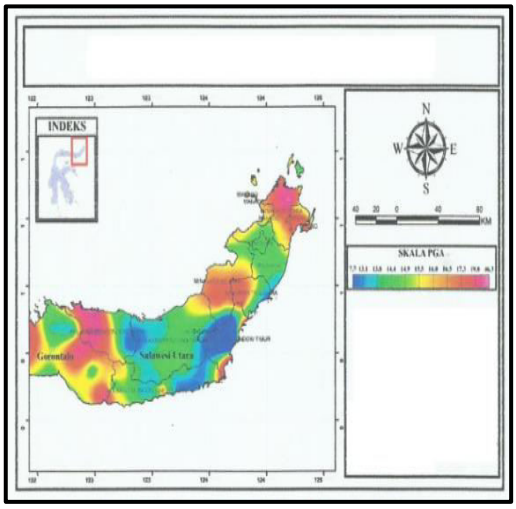

Figure-5. PGA map of north sulawe.

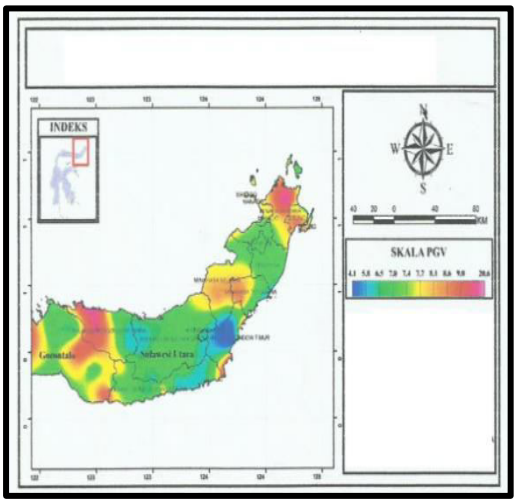

Figure-6. PGV map of north sulawe.

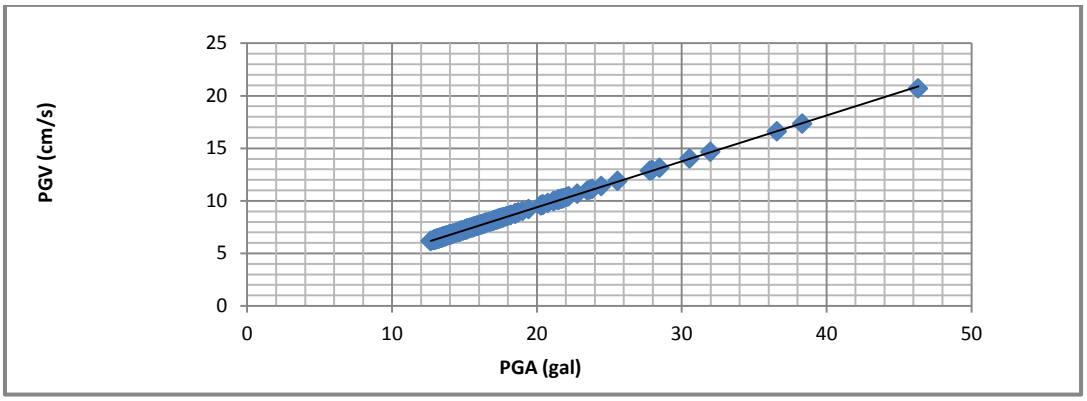

Figure-7. Curve of relationship between intensity PGA vs PGV.

In this study we used the intensity earthquake ≥ 4.5 SR. the empirical relationship between PGV and PGA with the intensity MMI determined by using linier regression we calculated relation between PGV and PGA with MMI as:

$MMI = 4.3 \log PGV + 2.2$ for 5< MMI<9
$MMI = 4.81 \log PGA - 1.5$ for 5<MMI<9
$PGV = 0.48PGA - 0.06$

CONCLUSIONS

a) The north Sulawesi has a high earthquake level considered spread of the land and sea Source of the earthquake areas north Sulawesi located in the sea due to the collision between a bow islands east of north Sulawesi and west halmahera that produces penunjaman ridge mayu, north Sulawesi penunjaman due to the collision between a bow volcanic north Sulawesi islands with a bow, and a bunch of a geological fault active on land.
b) Base the calculation by use the linear regression on obtain as:

$MMI = 4.3 \log PGV + 2.2(5< \text{MMI}<9)$
$MMI = 4.81 \log PGA - 1.5$ (5<MMI<9) $PGV = 0.48PGA - 0.06$

c) The value of the peak ground acceleration (PGA) and Peak Ground velocity (PGV) largest at north Sulawesi in the 2003-2014 with a preliminary magnitude of ≥ 4.5 SR are located in district of east Bolaang Mongondow i.e. the PGA of 46,33 gal and PGV of 20.67 cm / s. This is because at the area there are fault of Bolaang Mongondow and the influence of sangihe subduction.

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